FINAL REPORT

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IMPROVED TECHNIQUES FOR SCHEDULING SHIPYARD WORK

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In Behalf of
SNAME Ship Production Committee Panel SP-8
on
Industrial Engineering

Under the
NATIONAL SHIPBUILDING RESEARCH PROGRAM

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Task 8-90-3

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PREFACE

The National Shipbuilding Research Program seeks to improve productivity within the shipbuilding industry. An important part of this Program is carried out by SNAME Ship Production Committee Panel SP-8 on Industrial Engineering. The research effort reported herein is identified as NSRP Task 8-90-3.

This Task investigated a different approach to scheduling shipyard work. It asked the ***production segment*** of a shipyard what they felt they could best utilize in the way of ***support*** from the other segments of the shipyard. A utopian listing of items was generated, after which those items were reviewed by the support activities to see how dfficult it might be to provide them. Although attempts to actually provide and utilize those items were not **realized,** conclusions and recommendations based on the information developed are included in the Report.

This Task was conducted by Peterson Builders, Inc. of Sturgeon Bay, WI. Task Director was Ms. Karen Diedrick, Industrial Engineer at PBI. She was assisted by Rodney A. Robinson, Vice President of Robinson-Page-McDonough and Associates, Inc.

EXECUTIVE SUMMARY

Shipyard managers face a difficult task in deciding how much up-front preparations to afford in approaching a ship construction contract. While there are arguments in favor of extensive preparations as an eventual cost saver during the subsequent production activities, such preparations are expensive, and require thoughtful decisions on just exactly ***what*** should be provided.

This Project was designed to answer some of the questions associated with such preparations. Interviews were conducted with the production segment of a shipyard to identify in detail what items of support ***they*** felt they would need to receive from the other segments of the shipyard in order for the production processes and activities to be carried out most productively. A collection of support items was assembled that reflected ***only the production point of view.*** That is, the support activities in the shipyard were not involved in making this determination, and did not influence the listing in any way.

After the "utopian" list was assembled, the support activities were asked for their opinions on the degree of dfficulty involved in providing what the production segment had requested of them. Their answers indicated a high degree of ***capability*** to provide the items on the list, if the necessary personnel resources were made available within their support segment and insufficient time was allotted for their accomplishment.

The next step intended for this Task was to actually ayyly the findings on a representative construction contract, thereby providing the production segment with as much of what they had requested as practical. The benefits would then be measured. Judging from the large number of items that ***could*** be provided without difficulty, this step might have been able to demonstrate the real value in up-front preparations. Unfortunately this step was not reached due to the declining workload and the ensuing personnel down-sizing at the host shipyard during the performance period of this Task Because the project ended without the completion of all tasks, approximately forty-five percent of the funds were not utilized. Conclusions from the data collected and associated recommendations are included in the Repoxt.

Recent evaluations of European shipyards have disclosed the remarkably high degree of up-front training, planning, scheduling and material preparations carried out there. These efforts have placed them virtually in control of the international commercial marketplace. They do not *start* building a ship until they can see their way clear ***finish*** it without any delays whatsoever. They maintain ***prodution momentum*** throughout. By comparison, U.S. ship construction efforts seem to be constantly affected by problems with support or performance, requiring stops, waits, and restarts that destroy any production momentum that might have been achieved. The results are clear. They are busy and are making money. U.S. shipyards are rapidly going out of business. Perhaps a closer look should be taken at what the production people say they need to do their jobs, especially since most of their requests **can** be satisfied. This might be a good starting point on the road to recovery.

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IMPROVED TECHNIQUES FOR SCHEDULING SHIPYARD WORK

NSRP Project 8-90-3

BACKGROUND

This Project was sponsored by SNAME Ship Production Committee (SPC) Panel SP-8 on Industrial Engineering. The Project's goal was to investigate the shortcomings of traditional planningand scheduling techniques as they have evolved in the shipbuilding industry.

Planning and scheduling techniques for shipbuilding have developed, at least in part, on the basis of questionable information about the true production capability in the shipyard, and the most productive sequence for constituent operations. Plans and schedules are developed top-down to suit contract windows. Estimating the labor content of necessary work is done only in large increments using experience anc/or return costs for similar work (if available) or by best guess. Unbalanced workload/workforce at the work package level is common and usually is identified too late for recovery actions to be carried out without impacting the overall contract.

For survival in this environment, slack is built into the plans and schedules in order to minimize the consequences of inevitable impacts. Since the plans and schedules for production labor therefore do not reflect (in real time) the true needs of the production activity for support by those groups outside of production there is simply no way to achieve the critical balance needed between support and performance, a balance that is absolutely essential for success. Such matters as material identification and delivery, facilities readiness, design/engineering package sizing and publication, planning information for shop/trade loading and leveling, progress/financial status information and indeed the basic design itself, are often untimely or inappropriate to the true needs of production people and their management. In actual practice, the operational plan is forced to accommodate itself to the support that will be forthcoming, rather than to the support truly needed by production. The overall build strategy is therefore less than optimal, creating a situation within which it is *impossible* for the productive capability of the shipyard to achieve its maximum peformance.

In order to explore this problem area and identify how improvements might be achieved, SNAME SPC Panel SP-8 sponsored this Project for performance during NSRP fiscal year 1991. A Request for Proposal was issued by the NSRP Program Manager for Design and Engineering from the lead shipyard for this area, Newport News Shipbuilding (NNS). Peterson Builders, Inc. (PBI) of Sturgeon Bay, WI responded with a proposal

dated 20 March 1991. After review of the proposals received, a competitive award was made to PBI for the performance of this Project. NNS Purchase Order P2283T-O-N6 was issued to PBI on 17 September 1991. Work began in February 1992.

OBJECTIVE AND TECHNICAL APPROACH

The overall objective of this Project was to investigate techniques for scheduling shipyard work by looking for ways to more effectively sequence shop/trade participation analyze plans and locations (shop vs. shipboard), and reduce the expensive and disruptive "slack time" currently in schedules.

Three separate but closely related tasks were established: (1) to investigate the true performance capability of each segment of production (shop/trade/area); (2) to explore how shipyard work should be sequenced, where it should be performed (shop/ship), and how the efforts of the several shops/trades involved might best be interlaced to produce the most timely and least expensive final product; and (3) to determine the best ways to communicate to the support activities exactly what is needed from them to enable production to peform at maximum efficiency and effectiveness, and then to arrange for that support to be provided on time and in the proper configuration.

Each task would be treated through extensive discussions with virtually all levels of shipyard management, both in production and in the supporting activities. The three tasks generally would be prosecuted sequentially, although opportunities for overlap would be exploited. Each task is defined below. (NOTE: Task B and Task C were not actually accomplished, as discussed later in the Report.)

Task A-Define Utopian Build Strategy Requirements

This task would seek to identify how the approach to existing work in the shipyard is actually constrained by support systems and activities, and/or by contractual requirements. An initial production-oriented strategy would be developed, based on the best ways to apply the production effort involved. This determination would be made by working exclusively with the production side of the shipyard, in order that all constraining influences might be removed from consideration. The true performance capabilities of each segment of production would be defined, based on ***no*** support constraints.

Task B-Develop Plan and Schedule without Constraints

This task would develop a plan and schedule for a selected construction project with a build cycle that would support the Project. The only constraint applied to the plan would be facilities information from Task A. Design support, material arrival, and other considerations that usually control the build strategy would be ignored.

Task C - Develop Support Requirements to Meet Optimal Schedule

Using the schedule from Task B, support requirements necessary to allow production to perform according to the schedule would be defined. A means of actually developing and providing such support would be explored. The specific time frame and other constraints for the items of support needed would be developed in detail, along with careful identification and description of each support item. Ways to focus and direct support efforts to produce these items would be investigated. This Task would highlight those constraints that can be broken through shipyard efforts, and those constraints that cannot be resolved from within the shipyard.

DETAIL DESCRIPTION OF PROJECT ACTIVITIES

Task A - Define Utopian Build Strategy Requirements

Kickoff Meeting

A kickoff meeting was held with representatives from several affected areas of the shipyard, specific-ally Engineering, Planning Project Management, Production Shop Management, and the Operations Manager. The nature of the Project was explained, and a general course of action was defined. As the first step, a series of interviews would be conducted with members of the several shops/trades and their supervision to focus on precisely ***what*** items of support the production segment of the shipyard feels that they can best utilize, and ***when*** each item of support is needed. A comprehensive listing of support items would be developed, with the reasons ***why*** the production segment feels they can best utilize items of that particular kind. The listing would include

Planning items - overall build strategy, all documents (work orders - sizes, types, coverage, timing), workforce/workload analyses

Material items - identification ordering, vendor deliveries, storage location, issue arrangements, quality condition

Engineering items - drawings, CADAM, daily support

Quality Assurance items - what when by whom, audits

Facility items - in shops, on ships, in shipyard, numbers, types, maintenance strategy, loading profile

Labor expenditure collection items - where, when, how, audits

Program Management items - reporting, assessments

Accounting items - whatever specific entries are made by the shipyard

Workforce availability items - hiring training, qualifying, motivating

Scheduling items - generic types, sizes, issue points, coverage

and whatever else is involved in the generaI category of “support”.

After the listing has been assembled, each item on the list would be analyzed to determine the “ease of accomplishment” status most suitable for that item. Each item would be placed in one of three categories, based on the circumstances surrounding the potential accomplishment of that item. A definition of each category is provided below, along with the symbol assigned to that category for use in the remainder of this Report.

🡅 The first category covers those items that are already being provided, or could be provided by the appropriate support group without excessive difficulty. The capability to provide the item would be based on (1) the existing knowledge of the item itself, (2) the current state of personnel training and/or technological posture within that support group; and (3) the presence of existing processes and procedures which could be readily adapted or modfied to satisfy, that item. The capability to provide the item would also depend on a management commitment to provide the personnel resources within that support group to match the workload created by treating the item, along with provision in the overall schedule of the time needed to handle it. It is recognized that such a management commitment might or might not, actually be made. If it were made, however, then the support group would be capable of satisfying the item through a reasonable application of effort.

⇔ The second category covers those items which could be provided, although with *more dficulty* than with the items in the first category. The capability to provide the item would likely depend on (1) additional investigation and analysis of the item itself, (2) additional personnel training or technological advancement within that support group; and (3) extensive alteration/expansion of existing processes and procedures, or the creation of new processes and procedures, to satisfy that item. As with the first category, the capability to provide the item would also depend on a management commitment to provide the personnel resources within that support group to match the workload created by treating the item, along with provision in the overall schedule of the time needed to handle it. It is recognized that such a management commitment might, or might not, actually be made. If it were made, however, then the support group would be capable of satisfying the item, although with some difficulty.

∅ The third category covers those items that appear to be beyond the practical ability of the shipyard to provide in the foreseeable future. Even if a management commitment were made to provide the personnel resources and scheduled time allowance for the support group to treat the item, the level of effort and the extent of changes needed

to satisfy the item would be so great that accomplishment would not be feasible or likely within the next two or three years.

Interviews with Production People

A series of interviews with experienced members of the following shops/trades were arranged and conducted over a period of about five months:

Structural Fabrication
Structural Installation
Structural Outfitting
Welding
Pipe Fabrication
Pipe Installation
Machine Shop (Inside and Outside)
Paint Shop
Sheetmetal Shop
Electrical Shop

Each interview session was conducted in a comfortable and unthreatening atmosphere, with each person free to speak at any time and on any subject. Only production people were present during each session. Involvement and influence by supporting activities were entirely absent. The conversations were guided only to ensure that all of the important problem areas were covered before the group was dismissed. Each interview session was set up for one hour, at a rate of one session per week and typically included five or six production people plus the Project Director and her assistant. Three sessions were usually needed to complete the interviews with a shop/trade group, with some groups meeting only twice while others met four or five times. Careful notes were kept to capture the sentiment of the production people on each item discussed, which spanned the following topics:

Budget
Communications
Engineering
Facilities
Manpower
Material
Planning
Project Management
Quality Assurance
Schedule
Time Cards/Labor Expenditure Collection
Training
Work Orders
Miscellaneous.

iA total of **912** individual items of concern were identified from the interviews. Some of these items covered the same point in a slightly different way, and required resolution and combination. Others were of concern to the shipyard, but outside the scope of this Project. It was therefore necessary to purfy the listing, and to categorize the items for ease of analysis.

The items were sorted by shop/trade. A second sort was made by process/area of concern. After analyzing the listed items, it was decided to work with the process/area sort and combine the individual items into a set of reasonable expressions defining the needs within each category. This action would facilitate discussions with the activities responsible for providing that particular type of support. Once the listing was assembled, the production people interviewed were called back and asked to prioritize the items according to their perceived needs. A 'short list' of items, in priority order, was assembled.

Discussions with Support Activities

Each item on the 'short list' was discussed with the appropriate support activity to determine the "ease of accomplishment" status which they felt it should be assigned. The items of concern to this Project are listed below, by topic, and with the symbol indicating the "ease of accomplishment" status selected by the applicable support activity:

Budget (BD)

BD-01 🡅

The budget development process should include detailed input from the production shops/trades.

BD-02 🡅

Once the (work order) budget is established, the shops should be kept informed on a regular basis of details, changes, and progress against the plan.

BD-03 ∅

Work order estimates and the budget should be brought into strict and continuing agreement, and kept that way.

BD-04 🡅

The shops should only have to budget for items over which they have responsibility and control.

BD-05 ⇔

Guidelines for preparing the budget should be developed, issued, and followed.

BD-06 ⇔

The budget should be adjusted for unexpected and unanticipated changes in the workforce.

BD-07 ⇔

An annual budget made up *quarterly* should be tried.

Communications (CO)

CO-01 🡅

Planning and engineering both need a closer relationship with the production shops, leading to a better understanding of shop needs and capabilities.

CO-02 🡅

A system is needed to ensure that regular and detailed communications take place among all functional groups, but especially among engineering, planning, purchasing, and the shops.

CO-03 🡅

A system is needed to ensure that regular and detailed communications take place *within* some departments, such as within engineering and within planning.

Engineering (EN)

EN-01 🡅

Engineering needs to provide better support. They should be physically present more often in the production areas of the shipyard, and communicate regularly with the shops.

EN-02 ⇔

Engineering should use CADAM, with detailed input from the shops, to resolve interferences ***before*** they occur in actual production. The required order of installation sequence should be identified and communicated to the production people who must do the installation work.

EN-03 ⇔

Engineering should work toward no drawing changes and ***no*** engineering change notices. If a change <u>must</u> be done, shop input should be obtained to determine the cost, time, and quality impact of that change, and the details of it should be communicated to the shop as soon as possible.

EN-04 ⇔

The accuracy control aspects of drawings need improvement (baseline references, realistic tolerances on critical sufaces, etc.).

EN-05 ⇔

There should be ***no*** reservations on a drawing. If an area is uncertain, engineering should work to resolve the problem area before releasing the drawing to production for performance. If a drawing is issued 'for information only', it should be clearly marked that way.

EN-06 ⇔

Each engineering change notice (ECN) must be accompanied by the production hours needed by the shops to do the work. The cost to accomplish each ECN should be tracked, and this information should be made available to those investigating the basic cause of the ECN.

EN-07 🡅

Engineering should set up a system enabling rapid (5-minute) response to a phone call from a shop requesting on-site attention.

EN-08 🡅

The Bill of Material should be all in one location, rather than scattered around on several sheets.

EN-09 🡅

Temporary 'fixes' should be avoided. Permanent and final resolution of the basic problem should be pursued vigorously by engineering.

EN-10 ⇔

Engineering should provide *technical control* of all shipyard work, whether new construction, conversion, or repair.

EN-11 🡅

Engineering should examine the best material/method up front and design for producibility.

EN-12 🡅

Engineering should establish a standard reference (baseline) for locating items aboard ship. This reference should be used by both shipyard engineering and by the off-site design agent.

EN-13 ⇔

Clear and complete quality assurance and non-destructive testing requirements should appear on each drawing.

EN-14 🡅

Drawing changes should be marked *clearly* and *conspicuously.*

EN-15 🡅

Engineering should investigate each Production Change Request/Engineering Change Notice to ensure that it is legitimate and necessary.

EN-16 🡅

Fastener lengths and torque requirements should be clearly identified on each drawing. Reliance on finding such information on vendor drawings is inadequate.

EN-17 🡅

Engineering and other support areas in the shipyard should use a uniform and consistent system of numbering parts and material.

EN-18 🡅

The drawings issued to the shop should be smaller and include references so that they are easier to handle.

EN-19 ⇔

Engineering should regularly provide information such as that included in the "integrated design" package prepared for a recent bid. (This was a CAD-produced package resulting from extensive involvement by engineering and shop personnel.)

EN-20 🡅

Drawings should contain NDT, welding symbols, welding sequence, welding wire, weld sizes, how to weld, testing, stock numbers, torque specifications, and vendor information.

EN-21 ⇔

Drawings should contain all parts including method mounts, etc., to help in preventing interference problems.

EN-22 ⇔

Painting requirements should be completely specified on the drawings.

EN-23 🡅

Every weld should have a welding symbol or welding information. This irformation should be on the *drawing,* and not in the work order. Dissimilar metals should receive special attention.

EN-24 🡅

Drawing issue 'by module' is satisfactory, *provided* engineering has already seen and ***accepted the entire design.***

EN-25 🡅

Bulkhead drawings should contain a numbering arrangement tied to each blocking item.

Manpower (MP)

MP-01 ⇔

Hiring practices should include an interview with the people in the prospective shop/trade, to ensure that the ‘candidate’ is properly suited for the job.

MP-02 🡅

Workload curves should be kept, showing the projected needs against actual completion information and best estimates of future needs (rather than only against the original schedule). These curves should be realistic, and need to reflect the *actual* ***conditions in the*** shipyard.

MP-03 🡅

The shipyard needs an 18-month projection of workforce needs, issued monthly.

Material (MA)

MA-01 🡅

The shipyard should work toward buying for the least installed cost’ of an item, rather than the lowest purchase price. This is an ‘all-hands’ effort; the shops can provide information on the consequences. In some cases the size of material ordered can be important and sometimes it is important to order a certain brand.

MA-02 🡅

Vendors should be held accountable for on-time deliveries. All parts and material should be available on a scheduled date.

MA-03 ⇔

The whole area of material specification, packaging, receipt inspection, and quality assurance (at the vendor plant and at the shipyard) needs improvement.

MA-04 🡅

There should be a supply of common raw stock available within the shipyard.

MA-05 🡅

Material and equipment from a vendor should be accompanied by a complete and detailed listing of each piece. These parts should be on the Purchase Order and also in the Bill of Material so that the shop can order and receive only the parts they need.

MA-06 ⇔

The shipyard should install a ‘bar code’ arrangement for material identification and control.

MA-07 🡅

Fabricated parts should be inspected before they are passed on to the next shop.

MA-08 ⇔

Ordering of material from vendors should be timed so that the warranty does not run out too early.

MA-09 🡅

Instructional information on vendor equipment should be made available to the shops as soon as it is received, and even if it is not yet complete.

MA-10 ∅

Better labels are needed which can withstand blast and paint.

MA-11 🡅

There should be a consistent method of identifying parts.

MA-12 ⇔

There should be some significance in the part numbers.

MA-13 🡅

Up-front planning should identify which parts are attached to foundations, and which parts are left separate.

Planning (PL)

PL-01 🡅

Supervisors and crewleaders should be involved in the creation of the build strategy. The shop needs an up-front view of the contract and how the ship will be built.

PL-02 🡅

The Work needs to be sequenced properly. If the work were properly sequenced, there would be less re-work, less extra pre-fitting, and increased teamwork among the shops/trades.

PL-03 ⇔

Up-front planning and scheduling are needed. A planning and scheduling package, comparable to the ‘integrated design’ engineering package prepared for a recent bid, would be a good start. (This was a CAD-produced package resulting from extensive involvement by engineering and shop personnel.)

PL-04 🡅

Planning people need a better understanding of actual work and actual working conditions (e.g., application time and drying time for coatings, shop practices, etc.).

PL-05 🡅

Planning should not issue a work order unless it is ***ready in all respects*** to be started on the date indicated, and worked ***without letup*** until it is completed by the date indicated. Issuance of a work order 'for information only' should be clearly marked as such.

PL-06 ⇔

Work needs to be broken down into workable and manageable sections. For example, the bum shop needs to cut a whole plate at one time (this is more efficient, and reduces material handling operations).

PL-07 ⇔

The shop should be level-loaded with a certain span of workers.

PL-08 🡅

Project reporting should be updated against ***both*** the shop schedule and the central planning schedule.

PL-09 ⇔

Labor standards would be a nice tool. They should include variables for different situations.

PL-10 🡅

There should be a system to estimate the amount and type of material needed, besides experience.

Program Management (PM)

PM-01 🡅

When changes in work scope occur, the hours assigned to the shop should be altered to reflect those changes.

Quality Assurance (QA)

QA-01 🡅

The inspection sheet should be sent with the work order, and the shop should inspect their own work. QA personnel should perform ***audits*** of work and inspections.

QA-02 🡅

All **required** QA information should appear either on the drawing or in the work order.

QA-03 🡅

QA personnel should spend more time working with vendors so that material and equipment arrive at the shipyard in an acceptable condition.

QA-04 ↑

Everyone involved should be informed of the reason why a part is rejected, and what follow-up action is intended. If the shipyard is going to correct the problem, a work order should be issued promptly and the shop should be informed in detail of what actions are required.

QA-05 ↑

Receipt inspection needs improvement, both in requirements and in performance of physical inspections against these requirements. This should be done as far up-front as possible. Engineering should provide the technical requirements for receipt inspection, tempered by QA findings of an 'epidemic' nature.

QA-06 ↑

All shops should receive on-going quality training for the workers.

Scheduling (SC)

SC-01 ↑

Shops must stick to the schedules. Shops need to realize the impact that non-compliance has on other shops, even performing work early.

SC-02 ↑

There should be ***one*** schedule developed with input from all shops and departments. All work should be in the schedule, including support work performed by various departments.

SC-03 ⇔

Every schedule issued for performance should be realistic, credible, and performable. Issuance should be held up until these conditions are met.

SC-04 ↑

All necessary drawings, materials, information, sequencing, and detailed planning must be ***complete*** and ***available*** by the time a work item is scheduled to begin - the work start date. If it is not, then the schedule should ***not*** be issued for performance. If a schedule is issued 'for information only', it should be clearly marked as such. Schedules& need to be issued on time.

SC-05 ↑

Date information on each schedule ***must*** match the date information on each work order, and vice versa. When a change occurs it should be reflected in the schedule and work order dates.

SC-06 ↑

Subordinate schedules should be issued to meet each milestone date.

SC-07 ↑

A milestone schedule for the whole job should be issued up-front.

SC-08 ∅

Rescheduling should not be allowed.

SC-09 ↑

A subordinate schedule should show what is needed to be done over the next 2 months, with 2-weeks advance notice.

Time Cards/Labor Expenditure Collection (TC)

TC-01 ↑

There should be a better method of communicating work order numbers to those shops providing assistance to the lead shop, so that charging errors can be eliminated.

TC-02 ⇔

The shipyard should install a bar code arrangement for labor expenditure collection.

TC-03 ⇔

Bar code breakdown should be itemized to suit the needs of each specific trade/area, along with the degree of detail specified by planning.

TC-04 ⇔

There should be more detail in the time charges, but filling in the time cards should not be a job in itself

Training (TR)

TR-01 ↑

Practical training should be on-going for each trade/skill area, and should include the environmental and safety aspects of the work.

TR-02 ↑

There should be a comprehensive orientation and training program for new employees.

Work Orders (WO)

WO-01 ↑

Each work order should be tied to the schedules; all dates must match.

WO-02 ⇔

Engineering Change Notices should have their own work order number and hours assigned.

WO-03 ∅

Work order estimates and the budget should be the same.

WO-04 🡅

Assist work orders should always include the scope and a description of the work. They should also have hours assigned to peform the work, and should be considered in developing manning levels.

WO-05 🡅

Smaller work orders make progress reporting easier and more accurate.

WO-06 ⇔

A work order should be issued only if the work ***can*** start on the date indicated. Issuance of a work order 'for information only' should be clearly marked that way. All work order material should be available before the work order is issued.

WO-07 ⇔

Other information which should be included in a work order is whether lot numbers and/or heat numbers are needed; machining and drilling details; drawing numbers; scheduled start and finish dates; QA inspections required; fitter time allowances; types of metals involved, if dissimilar metals; welding details/processes.

WO-08 🡅

A work order should not 'carry-over' a long down period. Rather, the work order should be closed, and a new work order issued for the second portion of the work after the down period. Each work order should be 'open' only while the work can actually be performed.

WO-09 🡅

Work order size is not the critical attribute, only the abiliity to start or stop the work on time.

WO-10 🡅

Work order estimates should be realistic. This could mean the use of labor standards to develop the estimates.

WO-11 🡅

If a work order is large, there should be some sequencing within the work order.

WO-12 🡅

Each work order should be issued 2-weeks ahead of the start work date.

WO-13 ↑

A reasonable work order size might be 200 hours, with a range of 50 to 250 hours preferred.

WO-14 ↑

Another way to size a work order is to include the hours needed for l-week’s worth of effort.

WO-15 ↑

Notice of an up-coming work order should be issued 1 month in advance, and should be published every 2 weeks.

These items defined the type and extent of support that the production people felt they could best utilize in carrying out the construction processes. They represent the specific items of support that would result in the best performance by production. Since **most of these items show a ↑ for ease of accomplishment, it would appear that the** ***capability*** to provide this kind of support already exists, assuming the necessary resources were to be made available within each support area.

Task B - Develop Plan and Schedule without Constraints

Task B as proposed for this Project was to develop a plan and schedule for a ship without considering any constraints on the part of the support elements of the shipyard. This task would involve development of a plan which would ignore all problems with design support, material, and other factors which often influence the build strategy. Rather, it would explore the development of a plan which assumes that all support items will be provided on time and as identified by the manufacturing segment of the shipyard.

The proposal was written with the assumption that there would be a construction project at the shipyard with a build cycle which would support this project. This was not the case. Due to the time constraints of this research project, and the actual stages of the instruction contracts underway at the shipyard, it was ***not possible*** to actually “develop such a utopian plan and schedule.

One alternative considered, however, was to develop a plan and schedule without constraints for a project while it was still in the bid stage. This would assist the shipyard in bidding the work, and would provide a view of what ***could*** be done by production if indeed the constraints that they had identified earlier did not in fact exist, and if the information and input that they felt were needed, were in fact provided.

During discussions with shipyard marketing and bid department personnel, serious concerns were raised over this approach. These shipyard personnel did feel that a comprehensive and realistic build strategy would be crucial to a good competitive bid. It was felt, however, that if this were carried out for any particular bid at the shipyard, problems could arise if the constraints actually were ***not*** removed when the contract was

awarded. The estimates collected to develop the bid would have been based on the assumption that the constraints would not exist. Therefore the estimates would be inaccurate if the constraints and problems were not actually removed. Although these support personnel felt that most of the action items developed through the manufacturing interviews should be and could be implemented, this action could not be assured for any particular contract.

The alternative that was pursued for this Project was to examine the build strategy, problems, and opportunities for improvement on an existing in-house construction project. The construction project selected for this case study was a 51-foot aluminum patrol craft. The shipyard was carrying out a contract to build five of these craft, with an option for three more. At the time that this decision was made, the first hull was about halfway through construction. This case study also offered an opportunity to make some actual improvements for the follow on hulls.

Preparations for the Case Study

The construction of the patrol craft was being supervised by a hull supervisor and an outfitting supervisor. The work was being performed by craftsmen from all trades in the shipyard. This patrol craft contract was one of the first at the shipyard to serve as a pilot for a new MRP II system. Many people were therefore involved in using this new MRP II system for the first time, which-might bias the study. No other alternative was available, however, and so the decision was made to proceed with this action anyway.

To start the case study a kick-off meeting was held with various shop supervisors and the hull crew who had been working on the patrol boat. They were given a short history of the research project and its objectives, and their involvement with the project was discussed. The manufacturing personnel working on this contract were split into two teams for the sake of this project; the hull team and the outfit team. At this point in time the hull team had been working on the patrol craft for over a month, but none of the outfitting had been started. One item which was noted by management in this kick-off meeting was that at the start of this contract it was decided to cut ***one month*** out of the schedule. This month was taken from the front end of the schedule, thereby reducing the time available to Planning and Engineering before the start of construction.

Discussions with the Hull Team

The hull team met for one hour once a week for several weeks. During their meetings they brainstormed and discussed actual problems with the present build strategy and the related opportunities for improvement. Their goal was to identify and review the ***real problems*** that they were encountering, and define what could be done differently to eliminate or reduce those problems and thereby shorten the build cycle for such a patrol craft. They developed a good list of problems and ideas. After working on the contract for over a month they had already experienced problems in receiving the correct material and the engineering drawings on time.

Listed below are the ideas which they considered were likely to have an impact on the schedule and overall build strategy. Included after each item is a reference to the specific actions identified during the preparatory interviews with the production people where they described what they felt they could best utilize in the way of support, together with the indications from the appropriate support groups as to how difficult it might be to provide those items: ↑, ⇔, or ∅ as defined on Page 4.

Use 2 shifts of workers to get the work done sooner. MP-02↑

The roll over date could be pushed out in order to get more pre-outfitting done before rollover. PL-01↑ / PL-03⇔ / PL-04↑

Lay-offs occurring in the shipyard affect the morale and the learning curve. New people must be put on the jobs, others must get certified, etc. MP-01⇔

Company politics and policies affect morale and attitudes. Attitudes and morale affect the workers productivity. CO-02↑ / CO-03↑

In the current design the floor flats go through the longitudinals making it difficult to fit and weld. EN-01↑ / EN-11↑ / PL-02↑ / PL-03⇔ / PL-04↑

There is poor welding access on longitudinals to shell plate. EN-01↑ / EN-11↑ / PL-04↑

Time is being wasted running back and forth to the tool room. Time could be saved by having some of the tools available in the shop. CO-01↑ / CO-02↑

A small supply of shop material stock should be available for mistakes, changes, etc. MA-04↑

With the new MRP II system filling out time cards has become cumbersome. It is not always easy to find which charge number should be used. TC-01↑ / TC-02⇔ / TC-04⇔

Presently warehousing procedures dictate that immaterial is not available when the shop orders it they must re-order it. The material is not automatically sent to the shop when warehousing receives it. This can waste time both in waiting for material and in resubmitting orders. CO-02↑ / MA-02↑ / MA-03⇔ / MA-05↑ / SC-04↑ / WO-06⇔

The shop could use jib booms on the South side of the construction building. PL-01↑

The construction crew is not getting parts from the router shop when they are needed. CO-03↑ / SC-01↑ / SC-02↑ / SC-03⇔ / WO-06⇔

The material should arrive at the shop in a "package" or kit. EN-11↑ / PL-01↑ / PL-03⇔ / PL-04↑ / PL-06⇔

All of the parts should be cut in one location. The cutting operations should be closer to the boats to reduce travel. EN-11↑ / PL-01↑ / PL-03⇔ / PL-06⇔

The welders should clean up their own smoke and chips. CO-03↑

A vacuum suction cup tool would be useful for the shop to hold the aluminum shell plate. CO-01↑ / CO-02↑ / EN-01↑ / EN-11↑ / PL-01↑ / PL-04↑

The drawings are lacking some information. EN-01↑ / EN-07↑ / EN-10⇔

More pre-outfitting should be done on the bulkheads. It could not be done on the first hull because of the lack of information. CO-01↑ / CO-02↑ / EN-01↑ / EN-02⇔ / EN-10⇔ / EN-11↑ / PL-01↑ / PL-03⇔ / PL-04↑ / PL-06⇔

Methods should be employed to reduce the spatter when welding the side shell. CO-01↑ / CO-02↑ / EN-10⇔ / EN-11↑ / EN-20↑ / QA-01↑

Material flow of the parts should be streamlined. Some parts are going to the shop, then out for further processing and then back to the shop. CO-01↑ / CO-02↑ / PL-01↑ / PL-02↑ / PL-03⇔ / PL-04↑ / SC-03⇔ / WO-07⇔

It may cost less overall and save time to nest full plates, and scrap or save the drop-offs for later use. CO-01↑ / CO-02↑ / EN-01↑ / EN-11↑ / PL-04↑ / PL-06⇔ / WO-07⇔

Examination is needed to determine whether the scaffolding should be built into the jig or if regular scaffolding should be used. PL-01↑ / PL-03⇔ / PL-04↑

More up-front planning and engineering is needed before construction is started. CO-01↑ / CO-02↑ / EN-02⇔ / EN-04⇔ / EN-10⇔ / EN-11↑ / EN-12↑ / EN-13⇔ / EN-16↑ / EN-18↑ / EN-19⇔ / EN-20↑ / EN-21⇔ / EN-22⇔ / EN-23↑ / EN-24↑ / EN-25↑ / MA-13↑ / MP-02↑ / MP-03↑ / PL-01↑ / PL-02↑ / PL-03⇔ / PL-04↑ / PL-06⇔ / PL-07⇔ / QA-01↑ / QA-02↑ / SC-02↑ / SC-03⇔ / SC-04↑ / SC-06↑ / SC-07↑ / SC-09↑ / WO-01↑ / WO-04↑ / WO-05↑ / WO-06⇔ / WO-07⇔ / WO-08↑ / WO-10↑ / WO-11↑ / WO-12↑ / WO-15↑

There are a lot of missing or late drawings. EN-01↑ / SC-02↑ / SC-04↑ / WO-06⇔

There may be other facilities in the shipyard better suited for this type of construction. CO-01↑ / CO-02↑ / PL-01↑ / PL-03⇔ / PL-04↑

The longitudinals should be flatbar instead of angle. It would be easier to work with and would weigh less. EN-01↑ / EN-11↑ / PL-03⇔ / PL-04↑

If Engineering had more time before construction was started the shop would need less hours. EN-01↑ / EN-02⇔ / EN-04⇔ / EN-05⇔ / EN-10⇔ / EN-11↑ / EN-12↑ / EN-13⇔ / EN-16↑ / EN-18↑ / EN-19⇔ / EN-20↑ / EN-21⇔ / EN-22⇔ / EN-23↑ / EN-24↑ / EN-25↑

Management of this small contract has been made too complicated and cumbersome. CO-01↑ / CO-02↑

The hull team surveyed the list and identified which items could have an immediate impact, which items would benefit the follow-on patrol craft hulls, and which items would have an impact only on future contracts. This list was then reviewed with shipyard management in the manufacturing and planning areas. Many of the items they agreed with, and some of the items had already been recognized as problems and were being addressed.

The main problems and related opportunities seemed to be occurring in the Engineering and Material areas. The predominant factor appeared to be the fact that a month had been removed from the start of the schedule. This drastically reduced the time available to the engineering people, which resulted in drawings being issued late and/or with incomplete information. There was also a problem in getting some of the material into the shipyard on the promised delivery dates.

Despite the fact that these problems were identified during the construction of the first hull, realistically any changes made at this point would not have a significant impact until future contracts. This demonstrates how vitally important it is to have the correct up-front planning, engineering, and material support in place ***before construction is started.***

Discussions with the Outfit Team

The outfit team also met to discuss problems and opportunities to improve the build strategy. Although the work of the outfit team occurred later in the overall ship construction schedule, they still experienced problems resulting from the lack of up-front time for preparations. The listing that the outfit team developed from brainstorming their problems and potential solutions includes the following items:

Deck and bulkhead penetrations are missing on the NC plasma burn programs and therefore must be cut manually. (These were added to the third hull.)
CO-01↑ / CO-02↑ / EN-01↑ / EN-10⇔ / EN-11↑ / PL-01↑ / PL-02↑ / PL-03⇔ / PL-04↑ / PL-06⇔

The drawings are not fully developed, and therefore:

- **there is no Bill Of Material; EN-19⇔**
- **manufacturing must wait for drawings to do work; WO-06⇔**
- **there are problems with advanced buys; MA-03⇔**
- Purchasing does not know the size of equipment; CO-02🡅
- locations of equipment are not known, so electrical cables cannot be measured.EN-19⇔

Change orders are coming in late (there is not time to address them on a such a **small contract). BD-02🡅 / EN-03⇔ / EN-06⇔ / EN-15🡅 / PM-01🡅 / SC-08∅ / WO-02⇔**

The Electrical shop was not able to pre-outfit because the equipment was ordered late, the shop was still waiting for location informatio, and drawings were not available.
CO-01🡅 / CO-02🡅 / EN-01🡅 / PL-03⇔ /PL-05🡅 / SC-02🡅 / SC-03⇔ / SC-04🡅 / WO-01🡅 / WO-06⇔

The shops were not able to multi fab for several hulls initially.
EN-11🡅 / PL-01🡅 / PL-03⇔ / PL-04🡅 / PL-06⇔ / PL-07⇔

There is only one day between Dock Trials and Builders Trials which could cause **problems. SC-03⇔**

The shops are getting their drawings slowly. They are being spoon fed the **drawings one at a time. CO-01🡅 / CO-02🡅 / EN-01🡅 / SC-01🡅 / SC-02🡅 / SC-04🡅 / WO-01🡅 / WO-06⇔**

Material has been received late which has meant some items could not be installed **in the correct sequence. MA-02🡅 / MA-03⇔ / SC-04🡅 / WO-01🡅 / WO-06⇔**

The due date for some material is the day before the work needs to be completed.
CO-01🡅 / PL-05🡅 / PL-06⇔ / SC-03⇔ / WO-06⇔

The Pipe shop needs a cross reference for parts on the pick list such as the part number and specfics so that they do not have to go to the BOM to find out the **information on the part. CO-01🡅 / CO-02🡅 / EN-01🡅 / EN-08🡅 / EN-17🡅 / MA-05🡅**

All of the electrical parts are on one pick list which has caused some added work.
CO-01🡅 / CO-02🡅 / EN-01🡅 / PL-03⇔ / PL-04🡅 / WO-07⇔

The Electrical department needs the equipment or foundations in order to do cable **runs. This has been holding up their progress. CO-03🡅 / EN-01🡅 / EN-02⇔ / EN-10⇔ / EN-11🡅 / PL-03⇔ / PL-04🡅 / PL-05🡅 / SC-03⇔ / SC-04🡅 / WO-06⇔**

Engineering should complete the drawings in the order that piping or other items **need to be installed. EN-01↑ / EN-02⇔ / EN-10⇔ / EN-11↑ / EN-19⇔ / PL-01↑ / PL-02↑ / PL-03⇔ / PL-04↑ / PL-05↑ / SC-04↑ / WO-06⇔**

Follow-on Discussions with Both Hull and Outfit Teams

Discussions with the people in both groups revealed that there did not seem to be any significant problems with the originally intended sequencing of construction, or with the suitability of the individual pieces of planning work once they were issued. The problems were occurring because the ***overall*** planning effort for the project was disrupted and shortchanged. This in turn affected the sequencing of Engineering work, and reduced the time allocated for Engineering and material procurement activities. As a direct result, getting the material in and through the yard in a timely and efficient manner was a struggle that often fell short of the mark

<u>Task C- Develop Support Requirements to Meet Optimal Schedule</u>

Due to the workload situation in the shipyard at this point in the Project, it was not possible to carry out this Task. Review of the indicators of how difficult it might be to provide the utopian support identified earlier, however, shows that many of the problems encountered by Production and listed above quite probably ***could have been prevented*** by altering the support provided. Note the high numbers of ↑'s, which designates those items which are already being provided, or which could be provided without excessive difficulty, assuming the necessary personnel resources were made available within that support area. This suggests that the ***capability is available*** **to** head off these problems before they occur, and before they impact the production processes.

While it is recognized that enabling the resources of the support groups is expensive, the impact on the production processes of not doing so can be ***many times more expensive*** Reaching a desirable ***balance*** between these two mutually exclusive occurrences is the difficult task of management. Unfortunately, this Project was not able to accomplish its original intention of providing a measure of the value to be realized from providing the production people with the kind of support that they feel can best be utilized. It did demonstrate, however, that real life problems can be alleviated by proper support, leaving the judgment of whether to invest in such corrective actions with those managing the shipyard.

CONCLUSIONS AND RECOMMENDATIONS

This Project did not achieve the original intentions of developing an actual plan and schedule without support constraints, leading to a determination of the value that this approach might provide. However, a good definition was developed of those items that could be provided by the support activities in order for the production segment of the shipyard to perform most effectively. These items were then evaluated by the appropriate support activities to gain a measure of how difficult it might be to provide them.

Review of this information reveals that the ***capability exists*** to provide such support. This is a cause for encouragement, as many onerous and expensive production problems ***can be avoided*** through a stronger investment in supporting activities. While the expense of such support must be borne by the shipyard, it is likely that substantial overall cost savings would result, along with major reductions in the time required for construction of the ship.

Recent investigations (Reference A) have shown that comprehensive up-front training planning, scheduling, and material preparations for ship construction have placed the European shipyards in the forefront of the international commercial marketplace. It is recommended that United States shipyards carefully weigh the merits of similar activities to achieve efficient productive, and economical shipyard operations.

FINAL REPORT

IMPROVED TECHNIQUES FOR SCHEDULING SHIPYARD WORK, PHASE II - IMPROVED MATERIAL AVAILABILITY

PRESENTED TO

PANEL SP-8
NATIONAL SHIPBUILDING RESEARCH PROGRAM

PREPARED BY

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IMPROVED TECHNIQUES FOR SCHEDULING SHIPYARD WORK, PHASE II - IMPROVED MATERIAL AVAILABILITY

EXECUTIVE SUMMARY

This report, sponsored by Panel SP-8 (Industrial Engineering) of the National Shipbuilding Research Program represents Phase II of Project #8-90-3, "Improved Techniques for Scheduling Shipyard Work". Phase II looks specifically at the effects that late materials have on shipbuilding schedules, analyzes their contributing factors, and proposes remedial actions to minimize their effects.

Late material is a chronic, costly, and schedule-consuming problem for all shipyards. Usually, the problem is dealt with directly via expediters, emergency shipments, work-arounds, and, in extreme cases, redesign. This tends to alleviate the current problem on a short term basis, but fails to address the long term and broader issues that lead up to the late material in the first place. Looking at it from this more global perspective, late material should be more realistically considered a symptom of critical processes that are not suitably controlled or for which there is insufficient definition.

The overall problem is further complicated today by the fact that U.S. shipbuilders are undergoing a transition from an almost exclusively Naval market to one which is increasingly international and commercial in nature. This has several implications for the material management functions of a shipyard. Typically, this expanded and diversified market base will mean:

- less rigid material specifications imposed by a (commercial) contract,
- requirements for expanded supplier base,
- increased demand for metric materials (applies to both domestic Naval and international contracts),
- tighter delivery schedules,
- increased use of foreign and international standards.

As U.S. shipbuilders continue to introduce productivity improvements to the physical processes of ship construction, it becomes all the more important that material be delivered on time and in a condition that supports a more intensive use of precious manpower.

This report explores the processes that contribute to management of material and have the potential of contributing to late material deliveries, both from external (suppliers) and internal (interdepartmental) sources. in this context, "material management" is not confined to those job descriptions (purchasing, warehousing, material handling, etc.) traditionally labeled or implied as such. Rather, it is assumed that every function in the shipbuilding process that has the potential to affect the timely delivery of material is a material management function. These functions are categorized into five levels of effect and control, ranging from Corporate Policy (highly global effect, minimal local control) to Bid and Master Schedule to Engineering and Material Specification to Procurement and Material Control to Manufacturing, Testing, and Trials (low global effect, high local control). It is concluded that each have their own opportunities to affect material management at their own level and support other levels in that regard. These opportunities are detailed and discussed regarding their potential to enhance or degrade the material management function.

Based upon the exploration of the above processes, recommendations were developed aimed specifically at minimizing the occurrences of late material. starting at the highest level of corporate policy. Recommendations were driven by several guiding premises

- Late material is a symptom of poorly defined processes or processes out of control; usually the problem originated at a much higher level than is readily apparent.
- The contributing factors to the problem may be internal (processes, personnel, facilities) or external (suppliers, regulators, customers), but the solution is always internal in origin.
- There is no such thing as "non-critical" material.
- Too much or too early material can be as great a problem as too little, too late.
- Material management must be dynamic and it must be everybody's job.

Finally, recommendations were formatted into a model which could be applied to a wide range of shipbuilding organizations. In the development of recommendations, existing technologies or elements of them were employed wherever appropriate to mesh with current productivity trends in shipbuilding. For example, elements of Product Work Breakdown Structure and Group Technologies are promoted as means of rationalizing and simplifying material requirements, thereby allowing limited resources to be focused more keenly upon a reduced number of different items. Standardization of designs, material specifications, and processes is also strongly recommended as a means of early material identification leading to timely and quality material deliveries.

Cost/Benefit relationships are discussed in general terms with mathematical models presented as tools for individual shipyards in performing their own analyses. However, it usually takes no more than a cursory review of late material occurrences to realize the magnitude of the direct and indirect costs involved. Compared to these costs, the price of implementation of recommended basic improvements to processes can be readily justified.

1.0 INTRODUCTION

"For fhe lack of a nail, a shoe was lost, for the lock of a shoe, a horse was lost...", and so it goes. Just as the lowly nail in this ancient tale led to the loss of a kingdom, shipbuilding contracts are all too frequently brought to their knees by no-show materials, many times by relatively mundane items. Consider the cost and schedule impact of attempting a genset light-off when the genset is missing. Now, what if everything, including the genset were in place except for a $5 pipe fitting? What's the difference? There is none. In either case, manpower is idled, dependent activities are suspended, the milestone isn't met, and progress payment isn't made.

This may be a somewhat dramatic example of the depth and breadth of effect of late material deliveris, but it is by no means an unfamiliar scene in shipyards across the U.S. As U.S. shipbuilders strive to boost their productivity to world class levels, labor hours per ton of installed materials must inherently decrease. As each of those man-hours is accountable for the installation of more and more material, it's evident that it's becoming all the more critical to get the material to the job-site on time in order to fully utilize this increasingly valuable resource.

The strides taken in developing and implementing material management systems over the past two decades in American manufacturing, shipbuilding included have been nothing short of dramatic. MRP (Material Requirements Planning) was introduced in the late 70's to fill a void left by traditional material management practices, which was basically to react to material crises as efficiently as possible. MRP turned that around by looking to the future to avoid the crises in the first place, MRP II (Manufacturing Resource Planning) integrated MRP into all of the functions with which material planning must coordinate.

In the twenty plus years of its existence, MRP/MRP II has been continuously undergoing change due to the introduction of new management concepts (Just-In-Time, Lean Production, Flexible Manufacturing, etc.) to the point that it's barely recognized in its many hybrid forms. Each of these concepts are based upon sound economic principles, but as the competition among consulting firms and software developers intensified to make the technology more sophisticated, user friendly, and application-specific, these principles tended to get lost in the shuffle of the technology.

This report intends to revisit the principles upon which sound material management is based, not as a rebuttal of the state of the art concepts in practice today, but as a reaffirmation of their value as the foundation for the concepts. The use of the MRP acronym throughout the report is intended to be generic in nature, denoting any material management system based upon sound planning and coordination among company functions.

2.0 LATE MATERIAL - THE COSTS

By the time an item of material required on the job-site is discovered to be late or missing, its relative importance and associated costs in the overall scheme of things grows considerably beyond its original market value. Before attempting to analyze the problem and its contributing factors, an appreciation of the costs of the problem is necessary to put it all into perspective.

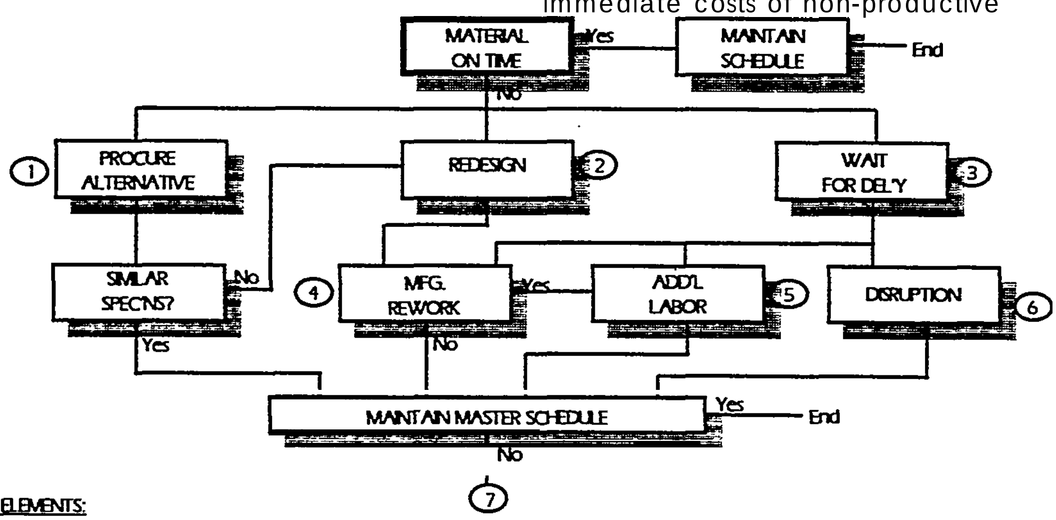
Figure 1 provides a diagrammatic view of the cost elements of late material deliveries. No attempt is made to quantify the costs here since they are subject to a wide range of factors which will vary from shipyard to shipyard and incident to incident. However, the basic cost elements involved and their interrelationships will remain fairly constant.

Probably the most easily recognized costs of late material are those most closely associated with the material itself. These include the (mainly) manufacturing labor idled and disrupted by the missing material and the additional costs of bringing the material to the job-site.

2.1 Idled/Disrupted Labor

The cost of idled labor is highly dependent upon the effectiveness of planning and the flexibility of the labor force. A non-union yard with *a* highly developed and implemented MRP system may be able to minimize the costs by flagging late material occurrences early enough to relocate workers to other areas of production.

However, while rescheduling workers around missing material alleviates the immediate costs of non-productive



COST ELEMENTS:

1 - Purchasing labor, communications, (phone, fax, mail), paperwork, material price increase (?(
2 - Engineering labor, disrupted design cycle, rework of related drawings
3 - expediting, revision of W.O.'s, plan work-arounds
4 - rip-outs, secure/unsecure worksite, damage to surrounding work, use of consumables
5 - overtime, bonus time, administrative labor (planning, material control, warehousing)
6 - suspension of dependent activities, loss of momentum, distraction from more proactive duties, reassignments
7 - delayed progress payments, liquidated damages, lost goodwill, lost opportunity

FIGURE 1

labor, the inefficiencies of rescheduled work cannot be ignored:

- actual time required to relocate and instruct workers on rescheduled work,
- time required to secure/unsecure area of workaround (temporary closures, tag-outs, staging, etc.)
- conflicts of space as workers are relocated to other job-sites
- dependent activities require concurrent rescheduling/disruption,
- lost efficiencies due to break-up of large batch work packages.

2.2 Administrative Costs

Administrative costs can be considered those directly concerned with alleviating a particular incident of late material. These are usually accrued by non-manufacturing personnel and include

- the tracking down and expediting of late material (labor hours, phone, and travel expenses),
- increased delivered cost of material due to expedited freight costs, special handling, and loss of price negotiating position,
- labor required to reschedule, reassign manufacturing labor, revise W.O.'s, B/M's, and master schedule,
- redesign (if necessary) to accommodate substitute materials and/or work-arounds,
- redirected engineering activities resulting in disrupted design/ procurement/construction schedule.

2.3 Lost opportunity

That the pursuit of late material is a non-productive and costly activity is readily apparent. What is not so readily apparent is the potential benefit that these negatively expended resources may have resulted in if they had been allowed to be used in a more positive effort. This is a far more nebulous area of cost accounting than the areas previously discussed, but its affect upon a company's growth and profitability are every bit as real, since it is in this area that companies set themselves apart from their competition. It's in this area of opportunity that learning curves are exploited to their maximum, that methods improvements are initiated, deliberated, and implemented, that new work is explored, and new ideas are tested.

Labor, cash, and time are finite resources. No matter how diligently management pursues the maximization of them, they will always be too few chasing too many objectives. Naturally, a certain percentage of these resources are devoted to building ships and simply staying in business. Beyond that, another portion of the company's resources are set aside for growing the company. Whenever negative activities such as late material require some of those resources, it's almost certain that they come out of the portion set aside for the growth of the business, even though most shipyard management would vehemently deny this.

The argument can be and usually is made that ***a*** certain amount of cost is built into a contract price to take care of late material occurrences and does not come out of a business growth budget which is usually an indirect account. This, of course is true and no one would suggest that any shipyard bid a contract without some

consideration for the realities of late material. However, there are only two places that this late material contingency can come from - profit or at the expense of the indirect accounts. Worst case is that a late material contingency is high enough to drive a bid price and/or delivery schedule into noncompetitiveness.

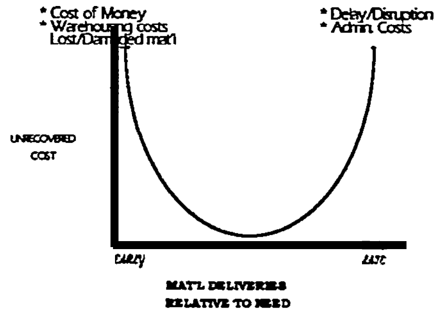


Figure II

Whether this has actually happened is purely speculative since no stipyard (or nonshipyard for that matter) accounting system is set up to capture the costs of late material with any degree of reliability. It's simply built into the "cost of doing business" as a discrete part of labor and overhead rates.

Further, the goal should not be to try to track these costs, but be aware of their rough order of magnitude and strive to minimize their impact upon first, the contract bid price, second, profits, and third, company growth.

2.4 Avoiding Whiplash

The short answer to minimizing the costs of late material seems to be to eliminate late material altogether via a super-conservative inventory system in which materials are ordered and stockpiled so far in advance of their need that the possibility of their being late is essentially eliminated. This does eliminate those costs associated with ***late*** material, but introduces a new set of costs due to the financing and warehousing of idle material.

Just-In-Time (JIT) material management seeks to find that portion of the curve (Figure II) whereby the costs of early and late materials are minimized.

3.0 MATERIAL MANAGEMENT IN A CHANGING MARKET

Shipbuilding today is a far different industry than it was ten or even five years ago, due mainly to the transition from Naval to commercial construction. As markets change, so do the material requirements and the methods employed to ensure on-time delivery.

3.1 Commercialization

The shift from a predominantly Naval shipbuilding base to commercial brings with it some implications for material management. For the most part, these are discrete changes, but changes that should be recognized for their potential effect upon current material management practices nevertheless.

Robably the most noticeable effects will be in the area of material specifications invoked by a contract. Traditionally, Naval shipbuilding contracts have come complete with a long list of very detailed material specifications. While this seems to provide an abundance of upfront ordering information, in reality, the specifications tended to be overly restrictive with a limited number of sources of supply. Items manufactured to MIL-SPEC or a NAVSEA standard especially those geared especially for a limited shipbuilding market are often treated as specials by the suppliers, requiring separate production runs, resulting in inherently longer lead times and higher costs.

The shifit to commercial contracts implies several changes in the area of material management

- Bid packages will generally have less specific material definition and tend to be more performance oriented. Bid preparers and designers will need to replace this information with internally generated information early in the contract stages to identify sources and quantify lead times.
- Periods of performance for commercial contracts are typically shorter than for Naval contracts, requiring correspondingly shorter material lead times and tighter adherence to schedule.
- Testing and certification for commercial material and equipment (if required) is less likely to be readily available than for their MIL-SPEC counterparts, so, while the item may be physically available earlier, its certification may take longer.

It should also be noted that recent directives issued by the Secretary of Defense mandate all of DoD to use commercially available items and non-government material standards wherever possible. This means that the gap between material specifications of Naval and commercial shipbuilding contracts will narrow over the coming years, but it will be a drawn out process and no one expects that Naval material specifications will ever look completely commercial.

3.2 internationalization

This issue goes hand in hand with commercialization, since the vast majority of the world’s fleet is foreign flagged and owned and will continue to be even with an upsurge of domestic flagged and owned newbuildings.

The internationalization of shipbuilding contracts brings with it challenges as well as opportunities. The challenge, of course has to do with the difficulties of dealing with foreign suppliers (language barriers, tariffs, customs, shipping, etc.), especially if they have no U.S. distributorship in place. These all have the potential of increasing material lead times and internal costs if adequate procedures and training is not in place to deal with them.

International and foreign standards are becoming a tool of the trade in today's world economy. Access to a wide array of the world's standards must be made available to designers, material specifiers, and procurement personnel and instructions provided on how to use them and compare them to their domestic counterparts. In many cases a foreign standard is essentially equivalent to a more familiar domestic standard which covers some more readily available materials.

3.3 Metrication

With the signing of Public Law 100-418 and Executive Order 12770, the U.S. federal government committed itself to converting its procurement practices to the use of the metric system wherever it was economically feasible. Not only is this having a direct effect upon shipbuilders as U.S. Navy contracts are let in metric specifications, but there will bean ever-increasing indirect effect as the U.S. manufacturing base responds to the federal government's demands for metric products. As the largest customer of manufactured goods in the U.S., the federal government's influence in the conversion of the private sector is indisputable. In addition, commercial contracts performed to foreign designs will undoubtedly specify metric materials and equipment.

4.0 MATERIAL MANAGEMENT FUNCTIONS WITHIN SHIPBUILDING PROCESSES

While the roles and responsibilities of material management have traditionally fallen to those personnel assigned to departments dealing with procurement, warehousing, and material handling, a closer examination reveals that virtually every person involved in the shipbuilding process from executive management to production has a material management function built into their job. It is therefore unrealistic to look simply at the traditional material managers for the solution to the problem of late material.

Material management must be looked at as an integral function of all shipbuilding processes starting well before the contract is signed and the first purchase orders placed and lasting well beyond delivery at the receiving docks.

This section will examine the processes involved in shipbuilding to identify those functions within which influence the delivery of materials to the job-site. The processes are grouped into five categories as illustrated in Figure III.

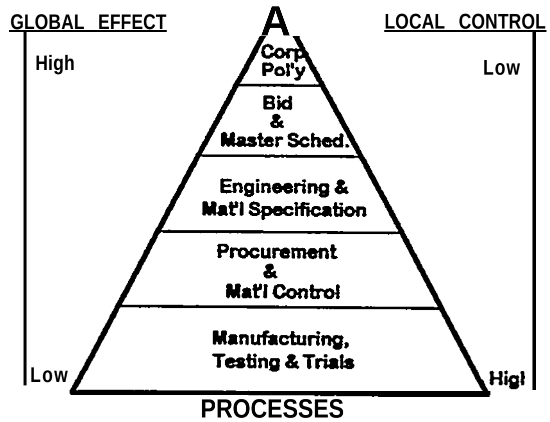


Figure III

Each of these categories will be examined based upon two fundamental questions.

First, what is the global effect of the actions and decisions made within this process? Obviously, global effect will be greater at the “higher” levels of processes, but the question to be answered is, “What specifically are the effects of actions and decisions on other processes?”

Second, what is the level of local control exercised upon occurrences of late material at each process? Local control can be considered more immediately concerned with and is quite often reactionary to individual occurrences of late material. Generalizing, a process’s local control will be inversely proportional to its global effect.

By examining these processes in terms of global effect and local control we can identify those actions and decisions which lend themselves to on-time material delivery.

A third area of consideration is the overall mechanisms by which the

processes communicate material related information to each other. This is not intended to get into MRP design, but only as a discussion of alternatives available.

4.1 Corporate Policy

It's unlikely that most CEO's and members of executive management consider themselves or their functions as material management. Yet, most of their actions will have a very definite effect upon subordinate processes in their ability to avoid late material deliveries. However, the connection between corporate policy-making and individual occurrences of late material are usually clouded by the fact that they may occur many months apart and, even then not be made visible at the corporate level.

For example, a high level decision to redirect marketing efforts must take into account a multitude of considerations, including material delivery and provide direction and resources where necessary to accommodate any changes required to fully support the new policy.

4.1.1 Management Accounting

The success of any planning and control system depends on how well the critical success factors are measured and reported. In order for upper management to set and adjust policy that is most conducive to alleviating late material, it must first have accurate and ***meaningful*** information relative to material deliveries.

Oliver W. Wright in ***"MRP"II- Unlocking America's Productivity"7y"J*** classified manufacturers as A,B,C, or D, based on how they use their material management (MRP) system. In a Class A company, the MRP system provides the game plan for sales, finance, manufacturing, purchasing, and engineering. A checklist (Figure IV) is provided to measure how well a company is operating its MRP system.

1.	**On-Time Delivery Performance %**	=	$\dfrac{\text{No. of Orders Received On Time X 100}}{\text{No. of Orders Scheduled to be Received}}$
2.	**Quality Performance**	=	$\dfrac{\text{No. of Units Accepted X 100}}{\text{No. of Units Delivered}}$
3.	**Bill of** Material **Accuracy**	=	$\dfrac{\text{No. of B.O.M. s Correct X 100}}{\text{No. of B.O.M. s Checked}}$
4.	Master **Schedule Execution %**	=	$\dfrac{\text{No. of Orders Completed On Time X 100}}{\text{Total No. of Orders Released}}$
5.	Material Nonavailability %	=	$\dfrac{\text{No. of Items Short X 100}}{\text{No. of Items as Stated in Inv y Records}}$
6.	**Routing Accuracy %**	=	$\dfrac{\text{No. of Routings Correct X 100}}{\text{No. of Routings Checked}}$

Figure IV

Some of the measures and their desired accuracy for Class A systems include

- Inventory record accuracy 95% or better,
- Bill of Material accuracy: 98% or better,
- Routing accuracy 95% or better,
- Master schedule performance 95% or better by item produced within the month,
- Shipping dollars: 100% shipped within the month,
- Shop delivery to schedule 95% or better,
- Vendor delivery performance 95% or better,
- Engineering delivery to schedule 95% or better.

The above are representative of criteria by which a shipyard's material management system may be measured, but are by no means all-inclusive, especially when it comes to identifying chronic and specific problems of late material deliveries.

4.1.2 Marketing

In these days of transition for the industry, it's not unusual to find a mix of military and commercial (domestic and foreign) construction coexisting in a shipyard. This market diversity brings with it equally diverse material requirements which must be acknowledged at the marketing decision levels. As limited material management resources are stretched to accommodate an increasingly diverse material mix and schedule requirements, the potential for late material deliveries increases accordingly.

While not likely to be an overriding consideration in the making of marketing plans, material availability must be a factor as these decisions are made. The issue will most likely come up as part of the decision of whether to integrate military and commercial work as one work group or separate them physically and/or administratively.

Material management in a commercial environment can be very different than that in a military environment. Generally, the differences to be expected going from military to commercial are

- less material specifications imposed by contract, more responsibility left to shipyard, design agent,
- shorter contract periods of performance, shorter material lead times required,
- broader base of qualified suppliers, more leeway in competitive bidding,
- fewer customer-imposed inspection, warehousing, handling requirements,
- more requirements for materials to offshore standards.

Depending upon an individual shipyard's perspective, the differences may be considered positive or negative, but regardless must be recognized as differences nevertheless and resources made available for the adjustments necessary.

4.1.3 Technologies

The efforts over the past decade to introduce new technologies into U.S. shipbuilding have been directed

primarily at reducing the labor content of ship construction, but at the same time have put more emphasis on the timely delivery of materials to the worksite. There are two reasons for this.

First, as the percentage of labor in a ship's construction cost decreases in proportion to material costs and as periods of performance decrease to world-competitive levels, the importance of material delivered on time becomes much more crucial in supporting high productivity levels and maintaining schedule.

Second, the introduction of new technologies brings with it inherent implications for material management which must be addressed in order to achieve optimum implementation. The conversion of a yard's work structure from Ship Work Breakdown Structure (SWBS) to Product Work Breakdown Structure (PWBS) requires carefully planned and executed adjustments in the ways that material is specified, ordered, and handled, even though the materials themselves have not been affected[2].

4.1.4 Corporate Culture

Corporate culture does not lend itself to hard-nosed scrutiny and analysis, since it is a rather nebulous attribute and constantly changing in very subtle ways. Yet, it plays a significant role in material management as it does in all aspects of ship construction.

If it is assumed, as stated previously that any personnel that have the potential to affect the timely delivery of materials (either into the yard or within the yard) are considered part of the material management function, the following questions are appropriate

- Is every worker, regardless of their assigned title, department, and primary job function aware of his/her responsibilities concerning material deliveries?
- Is every worker encouraged to be a "whistle-blower" when material deliveries are in jeopardy without fear of accusation or retribution?
- Are company-wide operating procedures defined in sufficient detail to inform all workers as to the processes of material management?
- Is there an atmosphere and mechanism that encourages constructive feedback in improving material delivery performance?

Corporate cultures are often grouped into two very general categories - traditional or progressive. There is no shipyard or any other company for that matter that would fit neatly into either of these categories, this being a very generalized view of an overall operation. Likewise, neither traditional nor progressive approaches can be espoused as the universally preferred approach to the challenges of material management. The appropriate approach for any shipyard is a blend of the traditional with the progressive that blends in turn with the overall corporate culture.

4.2 Master Schedule

Material management for an individual shipbuilding contract begins at the stage that the bid package is put together. It's also at this stage that many of the late material problems are

instigated with long-lasting and far-reaching effects.

Certainly, all proposed periods of performance take into account overall material lead times, but to what degree do they take into account the lead times involved in all the processes leading up to the actual receipt of the installation-ready hardware?

If we consider lead time as that period between the date that the demand for the material is identified and the date that it's actually installed, it can be bar-charted as shown in Figure IV.

Ideally, all material procurement processes down to Delivery of Software (see Figure V) would start as close to O month as possible, with as short of duration as possible. Assuming the date of final installation is driven by factors other that material availability, all processes from Delivery of Hardware on down would complete as near to Final Installation as possible.

Each of these processes should be looked at individually to determine their role in the overall lead time.

4.2.1 Stock Inventory

If planning stock inventory is difficult in most manufacturing industries, it's a black art in shipbuilding due to long construction cycles, uncertain market conditions, highly diversified product demands, and high cost raw materials and equipments. As economist Kenneth Boulding said, "Predictions are very difficult, especially those about the future"[3]. He might have added that the degree of difficulty is proportional to the distance into the future.

Nevertheless, shipbuilding relies to some degree on stock inventory driven by a combination of;

- historical data on commonly used materials (fasteners, plate stock, shapes, pipe, cable, etc.),
- speculation buys to hedge against unstable pricing,
- quantity buys to take advantage of quantity discounts.
- mass production runs of standard in-house produced components [brackets, collars, penetration assemblies, etc.).

While never intended to support ship construction by itself, stock inventory can be a very valuable tool in supporting early construction starts and buffering temporary shortages. The key question here is - at what point does stock inventory go from a tool of profit to a financial drag?

4.2.2 Material Take-off

Traditionally, material estimators are concerned primarily with coming up with a reasonably accurate quantity of materials that meet not only the contract's technical requirements, but the shipbuilder's budget and schedule requirements. Tools of the trade include contract specifications and drawings, inventory stock lists, vendor libraries, and design standards.

There are four basic types of information that must come out of the final material bid work sheets:

1. Material Specifications
2. Quantities required
3. Material costs
4. Material availability

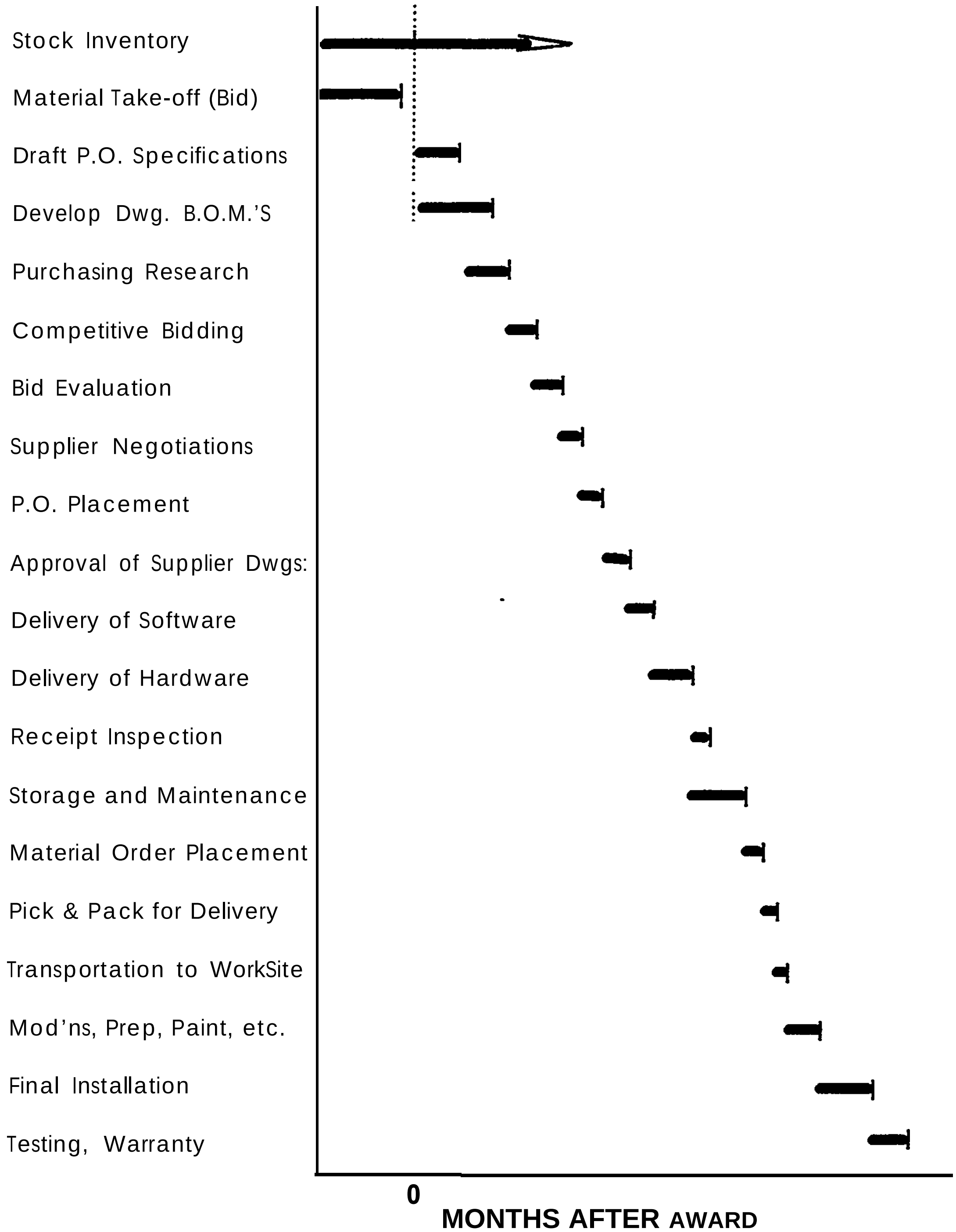


Figure V.
MATERIAL LEAD TIME ELEMENTS

In the crush of time typical of bid preparations, #4, material availability is the information most likely to suffer. The big ticket items (main engines, gears, deck equipment, etc.) and mass quantity raw materials (steel, pipe, electrical cable) are usually heavily scrutinized and delivery schedules locked in by contingent purchase orders or options. It's the low quantity, specialized materials (piping and electrical components, electronics equipment, custom components) that find themselves specified with insufficient regard to their ability to support construction and delivery schedules.

Contract specifications and drawings drive much of a material take-off effort and, for the most part are indisputable. However, it must be kept in mind that these documents were drafted primarily from a technical perspective with availability of the materials they specify being of secondary consideration, if at all. Although no bidder wants to present a proposal riddled with exceptions and alternatives, estimators should be made aware of this option when specified material availability and/or costs prove to be prohibitive and other technically equivalent materials are more suitable.

In the case of items requiring Vendor-Furnished-Information (VFI), this should be factored into the material take-off worksheets as prominently as the actual hardware, since late VFI can be as detrimental to a shipbuilding schedule as late material.

A shipyard's in-house design standards provide valuable guidance to material estimators since they have gone through a thorough process of adoption and specify known-availability materials.

4.2.3 P.O. Specifications

Items requiring P.O. specifications in advance of their complete engineering into the ship's design include

- standard raw materials requiring a mill or production run to fill the order (steel, pipe, cable, paint, shapes, etc.) in order to support early construction,
- standard equipment (by manufacturer's make and model) which require a separate production run by the supplier,
- standard equipment which requires non-standard modifications, either by the manufacturer or the shipyard,
- bulk quantities of standard items (fasteners, valves, electrical components, etc.) that would normally show upon a variety of drawing B.O.M.'s,
- outfitting items required to be "built in" during early construction,
- any item or material requiring testing and/or certification beyond normal manufacturing practices.

The purpose of advance P.O. specifications is not to have the material received in advance of its actual need date but to start the procurement process as early as possible in order to reserve production capacity for the order and provide as much float as possible in its delivery schedule. Delivery dates do not need to be firm at this point, but should give an approximation of need, erring on the conservative side.

4.2.4 Drawing B.O.M.'S

Drawing B.O.M.'S are the workhorse of material specifications. As such, their influence upon accurate and timely material deliveries cannot be overstated.

In order for drawing B.O.M.'S to be supportive of material need schedules, the drawings themselves have to be completed in accordance with a coordinated schedule. A major consideration here is the trend toward PWBS in ship design and construction. PWBS requires a complete rethinking of the structure, sequencing, and make-up of drawings from the "traditional" SWBS approach.

PWBS puts the B.O.M. to a whole new use. Under PWBS and MRP, the B.O.M. acquires a new function, in addition to serving as part of a ship's construction specifications. It becomes a framework upon which the whole planning system hangs and as such must go beyond its traditional role of basically an *engineeting* document. Historically, the function of the B.O.M has been to define the product from the design point of view only. But now, because we want to use it for the purposes of material planning, we must redefine the product from the manufacturing and planning point of view.

If the overall plan of production cannot be stated in terms of the B.O.M., it is not possible to plan material deliveries successfully. In reality, it is not the design of the product, but the way it is being procured and delivered to the worksite that dictates the format and content of the B.O.M.

For example, a standard manhole assembly may fit neatly into a B.O.M. as a single line item, but each of its components go through different manufacturing processes and sequences. The bolting ring must be fabricated and installed at the early stage of hull construction, while the cover, gasket, and fasteners are not needed until the enclosure is air-tested, probably weeks or months later.

The unit of work, or task is key here. If a number of components are assembled at different work stations and then forwarded to a final workstation for assembly, a subassembly number is required so that individual orders for the procurement and fabrication of the components can be generated and their priorities planned.

Thus, the B.O.M. is expected to specify not only the composition of a product, but the process stages in that product's manufacture. The bill must define the product structure in terms of level of manufacture, each of which represents the completion of a step in the build-up of the product. Figure VI is a representation of this product structure.

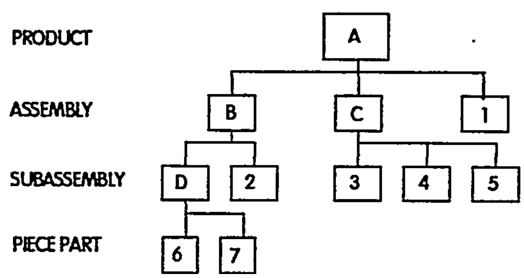


FIGURE VI

With this product-oriented Bill of Material structure, it is much easier to

track a materials progress and delivery, both from external sources and with the shipyard. However, having said this, while the entire product structure is chained together in the engineering database, it doesn't all have to be displayed that way. Single level B.O.M.'S area display of those components that are directly used in a parent item, showing only the relationships one level down. As a general principle, B.O.M. displays should be as shallow as possible, consistent with the yard's operations and needs.4

B.O.M. quantities must provide for sufficient material to execute the design. Beyond that, waste factors must be taken into account and this is often an area of confusion leading to quantity shortages and late deliveries.

Taking the manhole assembly mentioned earlier, the bolting ring material quantity could be stated in two different ways.

1. Neat- the quantity of material consumed by the finished design after fabrication and machining, or
2. Gross - the quantity of material required, including manufacturing trim to produce the finished design.

In some shipyards, material quantities are always stated as neat, with production engineers adjusting the quantities for actual needs based upon preferred manufacturing processes and nesting. In others, the B.O.M. preparer provides the gross quantity estimate. Whichever approach is used is subject to the individual shipyard's material planning organization and makes little difference as long as the responsibilities for waste allowance of all personnel involved are clearly stated and understood.

Concerning the actual description of material in the B.O.M., significant procurement and evaluation time can be saved through the use of design and material standards. In too many cases, materials are specified on the basis of individual preference or overly specific requirements without regard to what materials are being specified in other applications.

Design standards are those developed within the shipyard which prescribe materials, dimensions, and processes for the manufacture of procucts and assemblies commonly used in a the yard's ship construction.

Material standards are those that prescribe preferred materials for procurement outside the yard. These may be developed in-house or use outside sources of industry or government standards.

Standardization affects nearly every function within the shipyard, but it's driven primarily by the engineering functions since most of the materials and processes employed originate there. Standardization is simply the process of reducing the variety of types and sizes of items to a minimum consistent with the needs of an operation. A realistic appraisal of a typical contract material list and stock inventory list will usually reveal that a yard's material requirements can be adequately fulfilled by a greatly reduced list of items.

Standardization of materials naturally starts with design, before construction drawings and Bills of Material are translated into purchase orders. The avoidance of variations

from standards at this point makes possible a material management program involving fewer items with larger quantities of each. This results in pricing economies without overstocking inventory, fewer suppliers and more control over a limited number of orders.

The only justification for standardization in any shipyard is savings in man-hours, material costs, and schedule. Standardization, along with MRPII and JIT should not be approached as a goal, but as tools to attain a goal - in this case, improved material delivery performance.

The following provides a listing of some of the commonly recognized cost and time saving features of an efficient standardization program.

ENGINEERING
- Expands engineer's list of known and proven items
- reduces design time and material specification lead time,
- Reduces drafting time
- Reduces design and development on new items by increasing the level of detail design carried over from previous designs
- Reduces specification writing time by repetitive use of standard specifications
- Simplifies the selection and listing of common items

PURCHASING
- Increased Economic Order Quantities (EOQ)
- Fewer purchase orders
- Reduction of procurement research time
- Reduces misunderstandings and disputes with suppliers
- Reduces, simplifies negotiations
- Promotes better supplier relationships

MANUFACTURING
- Reduced material handling burden
- Higher volume- longer production runs on a setup
- Reduced inventory of special patterns, tools, and fixtures
- Increased uniformity of operations, more use of learning curves
- Reduced inspection and QA burden

MATERIAL HANDLING
- Delivery schedules more easily maintained
- Reduced material storage facility requirements
- Increased concentration on limited variety of inventory

GENERAL
- Reduced carrying costs of stocked inventory and W.I.P.
- Conducive to more effective planning and forecasting
- More efficient use of entire physical plant
- Simplified administration
- Improved interdepartmental coordination, reduced crisis situations

4.2.5 Purchasing

Once a contract's material requirements are conveyed to purchasing, several questions are brought into play which directly affect lead times. What are the Economic Order Quantities (EOQ) ? Are the material requirements best procured from external sources or produced in house (Make/Buy) ? Which supplier will provide the best performance in terms of quality, price, delivery, and service?

Even though these issues are focused by the purchasing processes, they must involve an array of inputs from design to manufacturing.

Any decision to make or buy must be preceded by an analysis of the capacity of existing facilities and manpower available. Issues to be considered include the number of shifts the facilities will be in operation, what overtime will be required, and what portion of the "make" may require subcontracting. Another important consideration that must be factored into the lead time is the construction or modification of facilities and equipment prior to actual production.

In most cases it is assumed that comparable quality is available from internal and external sources of supply. This is not necessarily so. When special tolerances or special skills are required in the manufacture of a part or assembly, the advantages of specialization may favor the buy decision. Any economies of in-house production are quickly lost in the redesign, rework, and lost time required to move a product from prototype to production.

These and other pertinent factors should be included in the list of factors to be evaluated in making the Make/Buy decision.

REASONS FOR MAKING	REASONS FOR BUYING
1. Cost studies indicate it is cheaper to make than buy	1. Cost studies indicate it is cheeper to buy than make.
2. Making fils your know-how, tradition, facilities	Space, equipment. time, and/or skill ore not available far you to develop necessary production operations.
3. Idle capocity is available to obsorb overheod.	3. Small volume or excessive capital requirements makes ROI unattractive.
4. Proposed product is unusual or complex for existing skills & facilities.	4. Seasonal, cyclical demand makes planning difficult.
5. Moking will focilitote control of parts, changes, inventories, and deliveries.	5. Need to concentrole on end product.
6. The product is herd to transport.	6. Patents or customer-supplier relationships favor going outside.
7. Avoid dependency on single outside source of supply.	

Figure VI
MAKE/BUY ANALYSIS5

In its traditional form, competitive bidding has been a double edged sword in the quest for supplier performance, including on-time material deliveries. On the upside, competing suppliers are motivated by natural market forces to put their best pricing and delivery terms forward in the hopes of beating out their competition. On the downside, it's no secret that suppliers "buy-in" to contracts with delivery schedules that they have no chance of meeting. Liquidated damages may be imposed (but not always accepted) on a contract, which will tend to mitigate the effects of ***late*** delivery, but this is a dismal second choice to having the material on hand when it's needed.

Competitive bidding over the past decade has taken on a new meaning in the context of JIT manufacturing. The buyer and supplier as partners approach is one of the cornerstones of

the whole JIT philosophy which has had such an enormous impact on international competition in many industries from automobiles to computers In this perspective, the emphasis for the buyer is placed on the development of close cooperative relationships with a relatively small number of carefully selected suppliers, with long term partnerships in mind. Closer coordination of schedules, cooperation on process and product improvements, and joint action on cost reduction all help to reduce inventory investment, while increasing overall levels of quality and service deliverable by the partnership to upstream customers.

A variation on the JIT philosophy is Vendor Managed Inventory (VMI). VMI takes the JIT partnership to the point where the vendor is invited into and made a player in the company's material planning process. Rather than extracting relevant information from the MRP master schedule and transmitting it piecemeal to the supplier, the supplier controls the flow of inventory into the shipyard's distribution network, based upon daily inputs of inventory, production demand, and work-in-process. The supplier determines the orders needed to satisfy the yard's inventory targets and production requirements and uses this information to not only schedule deliveries to the yard, but also to help determine its own manufacturing plans.

Some of the advantages of VMI include.

. Reduced lead time from demand identification to material delivery.
. Decreased manpower, paperwork for repetitive orders.
. Ability to maintain lower stock inventories.
. Supplier can do his own long term forecasting based upon his customers forecasted demands.

Some of the potential disadvantages:

. Yard's supply is only as good as the selected supplier.
. It's possible for supplier to load up inventory beyond need.

One of the tangential benefits of VMI is that it demands a solid material planning, monitoring and reporting system. Even then, VMI will only be of value to buyer and seller when material volumes are adequate and demands long term and predictable enough to justify this close relationship.

Some shipyards, especially European have taken the VMI concept ***a*** step further, allowing suppliers to set up warehousing and distribution facilities within the yard. Based upon the known inventory levels and projected production demands, the supplier will physically stock the materials needed to support production and distribute them directly to the worksite as requisitioned, thereby eliminating or reducing to a minimum the lead times required by the receipt, inspection, storage, handling, and distribution of materials using in-house facilities and personnel. Typically, suppliers have been in the areas of piping and electrical components, fasteners, and consumables.

Outsourcing of materials, services, and components is being recognized as a source of great competitive advantage. It's estimated that manufacturing companies spending

50% - 70% of their sales dollars on outsourcing and having a net profit of 7% would require $3.51 in sales in order to equal the savings accrued to the company for a one dollar savings in procurement. In the current shipbuilding environment of rapid technology changes, high investment costs, and global competition, the ability to accumulate and strengthen key competitive capabilities is typically beyond the capacity of in-house resources.

A number of factors have made widespread outsourcing possible. Computer Aided Design (CAD) and the revolution of electronic communications have led to global brainstormning among manufacturers and their suppliers. Aside from transportation and technological factors, an organization must have the appropriate mindset in order to outsource successfully- that is to trust and be able to work with outsiders. Also, the organization must be able to let goof the notion of total control and embrace the concept of Joint venture.

Outsourcing is reality for U.S. shipbuilders who intend to stay profitable - and in business. Arguably, its greatest obstacle is the traditional notion that "We don't sell ships, we sell man-hours". This becomes a heated topic, especially in union yards, but one that can and should be addressed in very objective terms to the benefit of the company's stockholders and labor equally.

4.2.6 Warehousing, Material Handling

Warehousing and material handling includes the responsibilities for

- receiving the material into the yard's material inventory system,
- inspecting (nontechnical) and verifiying compliance with Purchase Order specifications,
- storage of the material until called for,
- delivering the material to the worksite, and
- pick-up and delivery of Work-In-Process materials between worksites.

Within these processes are significant opportunities for late material deliveries. Even though late material deliveries at this point are measured more in terms of days, hours and even minutes, they are at least as significant as those due to external factors (supplier nonperformance) which are measured in units of days, weeks, and months due to the fact that schedule criticality by now has reached a much higher level and reschedule and work-around options are much more limited on short notice.

Warehousing's responsibilities for material delivery picks up where the supplier's and freight company's leaves off - at the receiving station. Receiving inspections must be made in a timely and accurate manner and reports of deficiencies made to the appropriate activities for remedial action when necessary. When technical inspection is required beyond that the capabilities of warehousing personnel, the necessary qualified personnel must be scheduled in to perform this function not as an afterthought, but as part of the material routing schedule.

The shelving of material for storage is a time-consuming operation that lends credence to the JIT concept. However, in reality, there are many

items in ship construction that do not lend themselves to JIT and these must be handled as expeditiously as possible. Bar-coding and highly precise (in some cases, hourly) MRP scheduling enable warehousing personnel to plan their work days in advance with the most efficient routing possible.

Conveyor and robotic sortation equipment is expensive, but in warehousing operations that handle large amounts of small, commonly used items, it can easily pay for itself in labor saved and lead time reduced. The primary benefit of automated sortation is, of course, the labor saved by eliminating both the need to transport the completed picks to the shipping dock and the need to sort together the components of each order. In addition, it provides an opportunity to scan the product as it's shipped, verifying its identity and ensuring that it's going to the right destination at the right time.

Point of Use storage, as opposed to centralized warehousing is clearly a technique that supports the successful implementation of JIT. Practically any shop in any shipyard can attest to the value of their "local" invento~. This is sometimes officially recognized by the material management system, but as often as not it constitutes unaccounted material. This somewhat clandestine implementation of Point of Use storage testifies in favor of the concept but fails miserably in promoting good material management practices.

Of course, one of the foremost concerns about implementing Point of Use storage is the requirement for valuable floor space at the worksite, but this, it must be assumed will be acquired through a reduction in W.I.P. brought on by the concurrent implementation of JIT.

Final delivery of material to the worksite by truck, forklift, or other means is the last opportunity for a material delivery to be delayed, if only by minutes. Overloaded delivery schedules, inaccurate routing sheets, unclear material markings, and confused pick-up and drop-off sites all lead to material delays to the worksite. A combination of a solid quality system with well-defined procedures and a finely-tuned MRPII system should address these potential problems.

4.2.7 Manufacturing, Testing, and Warranty

The effects of late material delivery are manifested at the worksite and it is here that the issue escalates from a scheduling problem to a manufacturing crisis. Labor is idled, dependent activities are suspended, overtime and rework costs soar, and the schedule slips, sometimes irretrievably. The issue gains in criticality as productivity gains in U.S. shipbuilding decrease the number of man-hours in ship construction. Thus, one hour of idled labor today is more detrimental to a contract's delivery schedule and profit than it was in less productive times.

Fortunately, there are numerous systems that provide communication and planning tools by which late material, when it is inevitable can be identified and suitable arrangements made to minimize its affects upon the manufacturing trades and production schedule. Of course, the ultimate objective is to eliminate altogether the potential for any late materials to get to

this point. Unfortunately, by the time a material is declared to be late, many factors (discussed earlier) have played a role in the situation that are beyond the control of the manufacturing trades. This limits the trades' material management function in these situations to a mainly reactionary one, that is to minimize the negative affect.

However, there are some factors that are in direct control of the manufacturing trades which can be addressed in a proactive approach to minimize the likelihood of late material. Lost or damaged W.I.P. is a form of late material as detrimental to schedule as material that was never received from a supplier. Shops with inadequate or disorganized storage facilities expend . excessive manpower in tracking and routing materials to their next processes. A production shop requiring a part or assembly from another shop in order to complete a work order on schedule is no better off than if the material required was delayed by an outside supplier. In this sense, the customer-supplier relationship is simply confined to two departments within the shipyard.

Shop inventories of commonly used materials and consumables (fasteners, tie-wraps, welding rods, lubricants, etc.) must be maintained at a level that ensures their availability to support the production schedule. A wide range of opinion exists concerning the range of materials and their stocking levels within the manufacturing shops (see section 4.2.6, Point-of-Use Storage), but regardless of a company's approach to the issue, these items must be readily available to the shop floor. The installation, start-up, and testing of a major piece of equipment can be held up by relatively mundane items of material not being on hand when needed and these must be managed with the same degree of attention as the major equipment itself.

Some shops tend to maintain a stockpile of JIC (Just-In-Case) stock which is basically unaccounted material which has been gathered over a number of contracts. To a degree, this entrepreneurial spirit is to be encouraged, especially if it is called upon frequently to alleviate late material occurrences. However, the existence of JIC stocks imply an underlying lack of confidence in the company's material management system and its ability to deliver on time. H also presents some problems with uncontrolled and excessive inventory costs and the potential for the installation of out of specification materials. JIC stocks will probably never be eliminated completely, but their existence should be investigated as evidence of larger underlying problems.

Testing and warranty work requires service and spare parts on hand to change out consumable (filters, lubricants) and damaged items. Consumables are usually best identified and managed at the shop level. Their use is fairly predictable and may be ordered with sufficient lead time to support the testing schedule. Damaged or worn items are much less predictable and require a much more concentrated effort to expedite their delivery. If service records are available for items of equipment, Mean Times Between Failures (MTBF) provide a tool in forecasting the need for on-hand spare parts. Beyond that, good relationships with the suppliers (in accordance with JIT philosophy) are

important in expediting the delivery of emergency items.

The best inspection and testing starts well before the equipment hits the shop floor and that is at the receipt of the equipment. Thorough inspection at this point will uncover many defects that would otherwise remain unresolved until their effects upon the schedule were much more critical.

5.0 PUTTING IT ALL TOGETHER

To fry to reach a set of definitive conclusions and recommendations applicable to a wide range of shipyards addressing an issue such as late material deliveries is a presumptuous undertaking. It first of all presumes that U.S. shipbuilders have not recognized or addressed the issue in the past. This, of course is not the case. Volumes have been researched and Written, both within this industry and throughout the world in a variety of industries on the subject of material management, one of whose primary goals is certainly to reduce or eliminate the occurence of late material deliveries. Some of this research has found its way into practical applications in U.S. shipyards with varying degrees of success.

It's indisputable that this management science has taken the manufacturing industries from the Industrial Revolution to the Information Age and contributed dramatically to the levels of production that we see today. Yet, management is still not satisfied. If material deliveries have improved 100% over the past decade, the competition has improved 110%. So the constant question before us is, "If we are all working with the same state of the art technologies, where do we get the extra 10% over the competition?"

The answer is in implementation, innovation, and continuous quality monitoring and improvement. The following table is an overview of a shipyard's typical operations as they relate to material management and specifically to the issues of late material deliveries. It does not presume that its recommendations have or have not been implemented in a particular shipyard. Rather, it's intent is as a broad view checklist focused directly at the issues of late material by which management can perform its own high level audit of its operations. The recommendations also do not espouse any particular management technology over another. MRP 11, JIT, PWBS, Lean Production Systems, Flexible Manufacturing, and numerous other state-of-the-art management systems all contain highly developed material management concepts that coexist and intermingle with each other. However, when broken down into their most basic elements we see recuring and common themes that are sometimes lost in the shuffle of computerization and reorganization that they entail

The basic elements that these recommendations are based upon are:

1. Process Definition - Until all the processes that contribute to material deliveries are identified and recognized as "material management" functions, they are unable to be controlled in a constructive manner.
2. Standardization - One means of more effective management of material is to manage less of it, or at least less variety. By concentrating limited resources upon a less diversified inventory, each item can be managed with more attention.
3. Continuous quality improvement - The ultimate objective is to reduce late material deliveries to zero. The only way to get there is by continuously improving the processes contributing to the deliveries.

The table is formatted according to the general processes of a shipbuilding project, with the following headings:

- Potential Problem Areas - lists actions and policies which tend to be conducive of late material deliveries.
- Recommendations (Proactive) - lists recommended actions to minimize the future occurrences of late material deliveries.
- Recommendations (Reactive) - lists recommended actions to minimize the effects of late material deliveries which have already occured.
- Feedback Mechanisms - lists other processes and the information/action required to implement recommendations.

PROCESS	RECOMMENDATION		MECHANISMS
	PROACTIVE	REACTIVE	
• CORPORATE POLICY DEVELOPMENT	• Establish operational procedures with clearly defined material management functions for all processes. • Establish policy and financial model for the maintenance of stock inventory . Establish build strategies early in contract stages which take into account material availability.	• Provide resources for expediting of latemateria	• Stategic planning • ISO 9000 certification, • Company quality program
• BIDDING	• Establish bidding procedures that take into consideration material delivery on on equal basis with cost ond quality. • Challenge unreasonable bid package specifications where material delivery is at risk, • Ensure that the proposed rooster schedule takes into account sufficient lead times for material (and software) delivery, inspection, set-up, modifications, testing, certain. • Bose bid on company - standardized designs and materials wherever possible, Ensure that bid materials which hove been identified with on unusually long lead time ore flogged to the oppropriate functions for special attention upon award.	• Review records of latematerial deliveries to develop performance histories for common materials and suppliers,	• Bid procedures • Company design and materiall standards, • Purchasing vendor files • Stock inventory catalog

IMPROVED TECHNIQUES FOR SCHEDULING SHIPYARD WORK, PHASE II - IMPROVED MATERIAL AVAILABILITY

PROCESS	RECOMMENDATION		MECHANISM
	PROACTIVE	REACTIVE	
• BIDDING (cont.)	• Make Make/Buy decisions hosed upon established company criteria,		
• ENGINEERING & MATERIAL SPECIFICATION	• Develop and use design and material standards which incorporate material availability into their approval process, • Use stock inventory wherever possible, . Establish standard materials and specifications to limit variety (shopes, outfitting items) within individual contracts . . Challenge contract specifications where they specify materials end/or equipment with unreasonable lead times, • Provide sufficient schedule and manpower for completion of Purchase Order specifications and drawing Bills of Material with sufficient lead time for delivery of materials. • Establish a library of Vendor-Furnished Information for commonly used equipments and materials, • Provide advance P.O. specifications for any materials which require lead times that can't be supported by its associated drawinq B.O.M.	• Provide timely alternative material and equipment choices to replace delayed items. • Provide timely redesign where necessary to accommodate late or substituted materials. • Review records of late material deliveries to develop performance histories for common materials and suppliers,	• Engineering procedures • Design and material standards • MRP II Principles • CAD (interactive) • Stock inventory catalog

PROCESS	RECPMMENDATION		MECHANISM
	PROACTIVE	REACTIVE	
• ENGINEERING & MATERIAL. SPECIFICATION (cont.)	Ž Provide real-time access to computer-generated B.O.M.'S for review and comment by purchasing and manufacturing personnel. • Establish guidelines for the allowonce for waste in the development of B.O,M. quantities. • Provide access to material and supplier performance records for designers and others responsible for material specification		
• PURCHASING	• Monitor material deliveries in advance of their ability to impact scheduling, expedite early. • Adopt JIT principles for long term relationships with suppliers, • Reduce research time through the use of material standards. • Establish sources for metric and foreign sourced materials in advance of their need. • Maintain and use material and supplier historical data. • Explore use of Vendor Managed Inventory,	• Provide expediting services for late deliveries. • Provide alternative sources for late materials, • Maintain records of delivery performance for common materials and suppliers, • Provide early notice to those effected concerning projected late deliveries.	• Purchasing procedures • JIT principles • MRP II • Material standards • Stock inventory catalog
MATERIAL HANDLING	• Establish material handling procedures that foster timely, efficient deliveries, Ensure thorough receipt and technical inspections ore performed at delivery, Minimize	• Provide expediting services for late deliveries,	• Material handlinq procedures • MRP II • JIT principles • Company quality program

• MATERIAL HANDLING (CONT.)	handling through scheduling deliveries to the worksite whenever possible in arccordance with JIT principles, • Establish routine delivery schedules and pick-up and drop-off stations, • Establish economical levels of Point-of-Use storoage of commonly used materials		
MANUFACTURING	• Establish clearly defined procedures that include material management responsibilities in the manufacturing trades. • Provide suitable storage and identification for W.I.P. • Place orders for consumables and spore ports in advance of their need. • Establish good working relationships with supplier service representatives,	• Provide early notice to those concerned of projected Iate deliveries of W.I.P.	• Manufacturing trades procedures • MRP II • Company quality program

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